# Contents

Abstract (Chinese)	I
Abstract (English)	III
Acknowledgements	VI
Contents	VII
Figure Captions	IX

## Chapter 1

Introduction	1
1.1 Overvie	ew of Organic Thin Film Transistors and Active-Matrix Pixel for
Novel of	display Applications1
1.1.1	The Basic Operation Mode and Principles of Organic Thin Film
	Transistors
1.1.2	The Carrier Transport in Organic Semiconductors
1.1.3	The structures of Pentacene
1.2 Motiva	tion10
1.3 Thesis	outlines12
	E ES P E
Chapter 2	

The Study on Polycrystalline Pentacene Thin Film Transistors	19
2.1 Introduction	19
2.2 Experiment	20
2.3 Result and Discussion	22
2.3.1 The Growth of Pentacene	22
2.3.2 Comparison of Top Contact and Bottom Contact Configurations	25
2.3.3 V <sub>th</sub> Model Proposed by R. Schroeder	27
2.3.4 Space-Charge Limited Current in Linear Region	29
2.3.5 Pentacene Bulk Traps dependent V <sub>th</sub> Model	31
2.4 Conclusion	33

Atmosphere Effect on Pentacene Thin Film Transistors.	50
3.1 Introduction	50
3.2 Experiment	51
3.3 Grain Boundary Potential Barrier Model	52
3.4 Result and Discussion	53
3.4.1 Atmosphere Effect on Top Contact Configuration	54

3.4.2 Atmosphere Effect on Field Effect Mobility	55
3.4.3 Trap Density Extracted by Levinson Model	57
3.4.4 Atmosphere Effect on Bottom Contact Configuration	
3.5 Conclusion	62

The Driving of Liquid Crystal Display by Pentacene	Thin Film
Transistors	73
4.1 Introduction	73
4.2 Experiment	74
4.3 Result and Discussion	75
4.3.1 Sensitivity to Humidity	75
4.3.2 Effect of Passivation Layer	76
4.3.3 The Illumination Effect	77
4.3.4 The Uniformity in Local Substrate	77
4.3.5 Gate Bias Stress	
4.3.6 The Driving of Display	80
4.4 Conclusion	
Chapter 5	

# Chapter 5

The Active-Matrix Pixel Structure Application in Field 1	Emission
Display	96
5.1 Introduction.	96
5.2 Experiment	97
5.3 Result and Discussion	
5.3.1 The Proposed Novel Pixel Structure	98
5.3.2 The Characteristics of Carbon Nanotube Field Emission Dis	splay100
5.3.3 The Driving Requirement and Result of Active-Matrix Field	d Emission
Display	100
5.4 Conclusion	102

Conclusions and Further Recommendations	
6.1 Conclusions	113
6.2 Further Recommendation	115
References	118
Vita	
Publication List	

# **Figure captions**

### **Chapter 1**

- Fig. 1.1 (a) Cross section view of inverted staggered type organic TFTs. (b) Cross section view of inverted coplanar type organic TFTs......14
- Fig. 1.3 The properties of an inverted coplanar pentacene TFT utilizing ITO as electrodes with channel width 10000  $\mu$ m and channel length 57 $\mu$ m. (a) The transfer curve of  $V_D$ = -50 V. (b) The output curves......16

2.1 The vacuum thermal evaporation system for pentacene	Fig. 2.1
2.2 The fabrication process flow of inverted staggered type pentacene TFTs	Fig. 2.2
with Au as contact electrodes	
2.3 The fabrication process flow of inverted coplanar type pentacene TFTs with	Fig. 2.3
ITO as contact electrodes	
2.4 The pentacene growth on silicon dioxide with different substrate	Fig. 2.4
temperatures of (a) room temperature, (b) 50 $^\circ\!\mathrm{C}$ , (c) 70 $^\circ\!\mathrm{C}$ , and (d) 90 $^\circ\!\mathrm{C}$	
respectively	
2.5 The pentacene growth on oxide with different surface treatment layer (a)	Fig. 2.5
without any pretreatment, just only oxide, (b) with HMDS treatment, (c)	
with a layer of polyimide, all with substrate temperature 70 $^\circ\mathrm{C}$	
respectively	
2.6 (a) The X-ray diffraction plot of Fig. 2.5(a)(c) samples, pentacene was	Fig. 2.6
grown on oxide or polyimide layer, respectively. (b) The enlargement and	
analysis of (a)	

- Fig. 2.10 (a) Schematic plot of cross section of inverted-staggered (top contact) device geometry (b) The corresponding cross section SEM image.......43
- Fig. 2.11 The top view SEM images of pentacene film with thickness of (a) very thin, (b) 65 nm, and (c) 106 nm, respectively, in the channel region......44
- Fig. 2.11 The top view SEM images of pentacene film with thickness of (d)143 nm and (e)167 nm, respectively, in the channel region......45

- Fig. 3.4  $I_D$ - $V_{DS}$  characteristics of a TC pentacene transistor measured in air and in a vacuum. The  $V_G$  was varied from -20 V to -100 V with -20 V step.....66

- Fig. 3.9 Plot of  $\ln(I_D/V_G)$  versus  $(1/V_G)$  for a TC pentacene transistor measured in air and in a vacuum with a  $V_{DS}$  of -20 V......70
- Fig. 3.10 (a)  $I_D$ - $V_{DS}$  characteristics of a BC pentacene transistor measured in air and in a vacuum. The  $V_G$  was varied from -20 V to -100 V with -20 V step. (b)  $\text{Log}(I_D)$ -  $V_G$ (left-axis) and  $(I_D)^{1/2}$ - $V_G$ (right axis) characteristics of a BC pentacene transistors measured in air and in a vacuum with a  $V_{DS}$  of -80 V......**71** Fig. 3.11 Plot of  $\ln(I_D/V_G)$  versus  $(1/V_G)$  for a BC pentacene transistor measured in air

Fig. 4.1	(a) The process flow of the inverted coplanar type pentacene TFTs84
Fig. 4.1	(b) The process flow for an active matrix TNLC display driven by inverted
	coplanar type pentacene TFTs85
Fig. 4.2	Log $(I_D)$ - $V_G$ (left axis, open symbols) and $(I_D)^{1/2}$ - $V_G$ (right axis, closed
	symbols) characteristics of a pentacene transistor measured in air (squares),
	in vacuum (circles), and in dry air after 25 hours of pre-test storage
	(triangles) with a $V_{DS}$ of -50 V. The channel width and length are 20000 and
	57 μm, respectively

- Fig. 4.8 The extracted threshold voltage and mobility of the results in Fig. 4.7.....92
- Fig. 4.10 Voltage-transmittance curve of TNLC......94
- Fig. 4.11 A 3 inch  $64 \times 128$  active-matrix TNLC display, (a) the monochrome type, (b)(c) the multi-color type with integration of color filter......**95**

Fig. 5.1	The process	flow of	the ac	ctive	-matrix	CN	Г-FE	Ds		103-5
Fig. 5.2	Schematic	circuit	and	(b)	layout	of	the	novel	active-matrix	pixel

	structure
Fig. 5.3	(a) Schematic circuit of the discrete devices including a diode CNT-FED
	and a n-type TFT with feature size of channel width 8 $\mu m$ and channel
	length 16 $\mu$ m, and (b) the transfer characteristics of (a) at different anode
	voltage107
Fig. 5.4	(a) The emission current versus voltage characteristics of diode-CNT FED
	that were measured from four different areas. (b) The current-voltage-
	brightness for a diode CNT-FED with 50 µm space distance108
Fig. 5.5	Two criteria of driving TFT that were depicted by TFT's output curves
	along with CNT's load line109
Fig. 5.6	(a) Top view of the multi-gates TFT and (b) the output characteristics of
	multi-gates TFT110
Fig. 5.7	The transfer curves of a single gate LPTS-TFT before and after 560 $^\circ\!\mathrm{C}$
	thermal process at $V_{DS}$ of -1 V and -10 V, respectively. The close symbol
	presents the case after thermal process and the open symbol denotes the
	origin case. The square symbol was the case at $V_{DS}$ of -1 V, and the circle
	symbol was the case of $V_{DS}$ of -10 V
Fig. 5.8	The image of 4 inch active-matrix CNTFED display driven by high voltage
	TFTs